SPECS

Seasonal-to-decadal climate Prediction for the improvement of European Climate Services

SEVENTH FRAMEWORK PROGRAMME

What I have done at IC3

Eduardo Blanchard-Wrigglesworth,

Institut Català de Ciències del Clima, Barcelona

&

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Developing a seasonal statistical sea ice model

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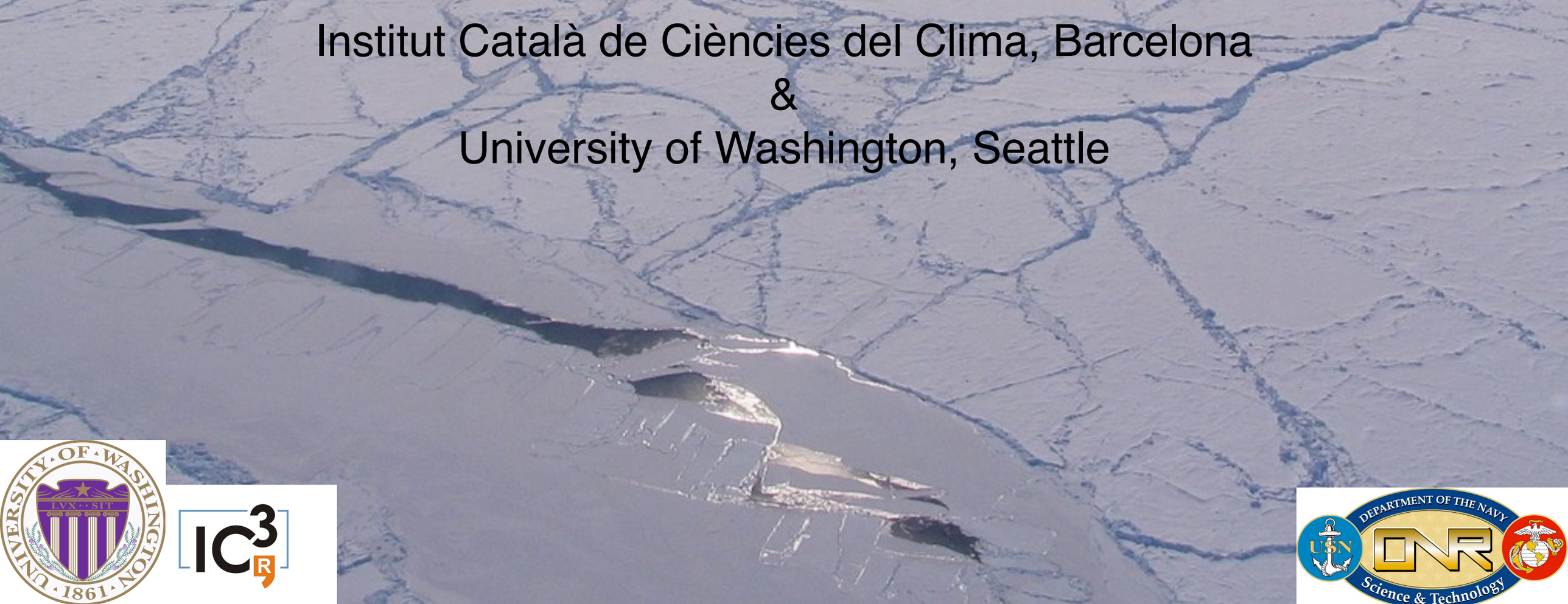
University of Washington, Seattle



Why develop a statisical sea ice model

Forecasts of September sea ice extent

Since 2008, effort to predict September sea ice extent (triggered by 2007 summer record melt)

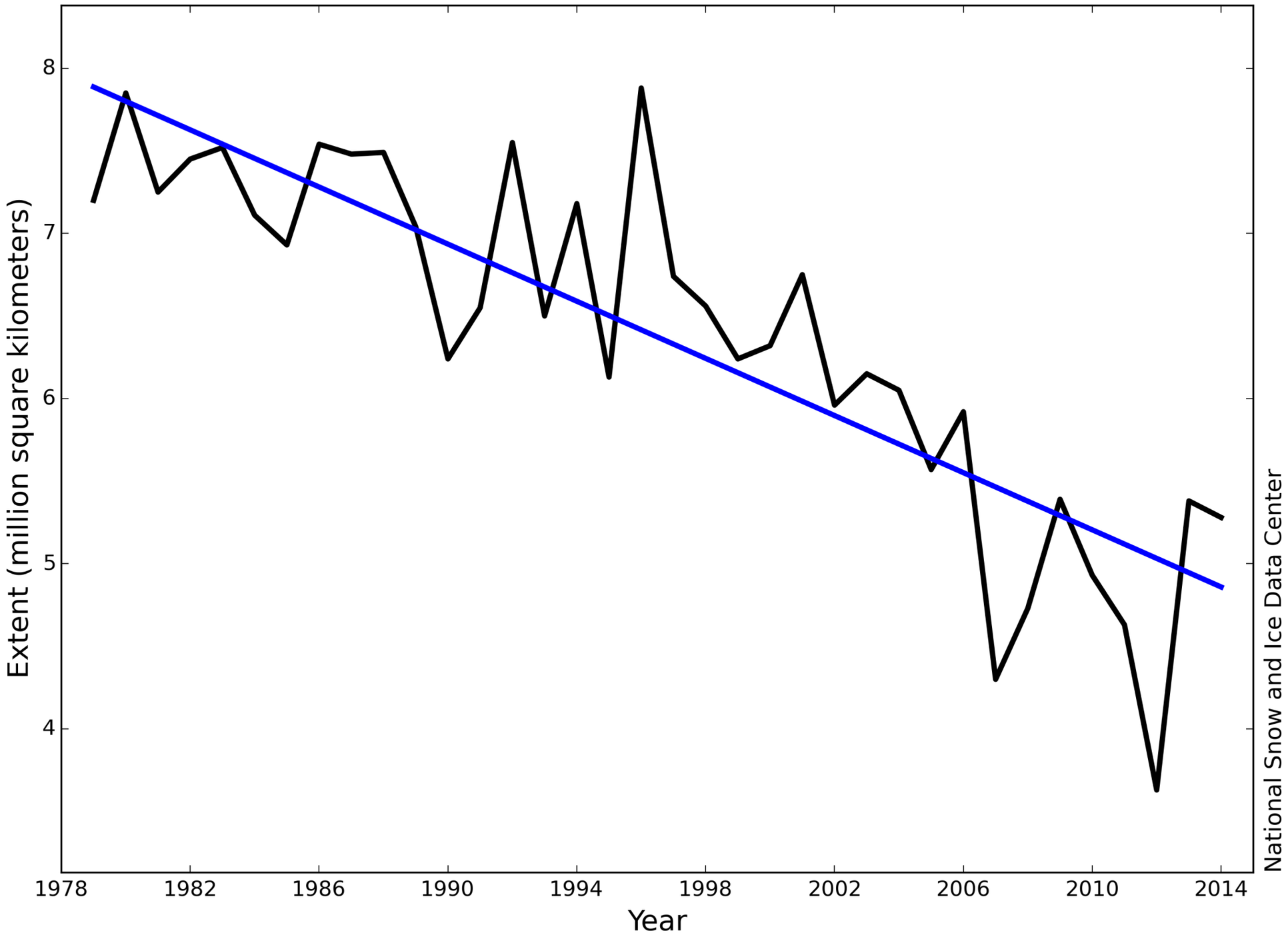
Organized by the Sea Ice Prediction Network (SIPN, http://www.arcus.org/sipn), each summer, 3 submission calls - early June, early July, early August

All types of forecasting techniques welcome: dynamical models, statistical, heuristic, public polls.

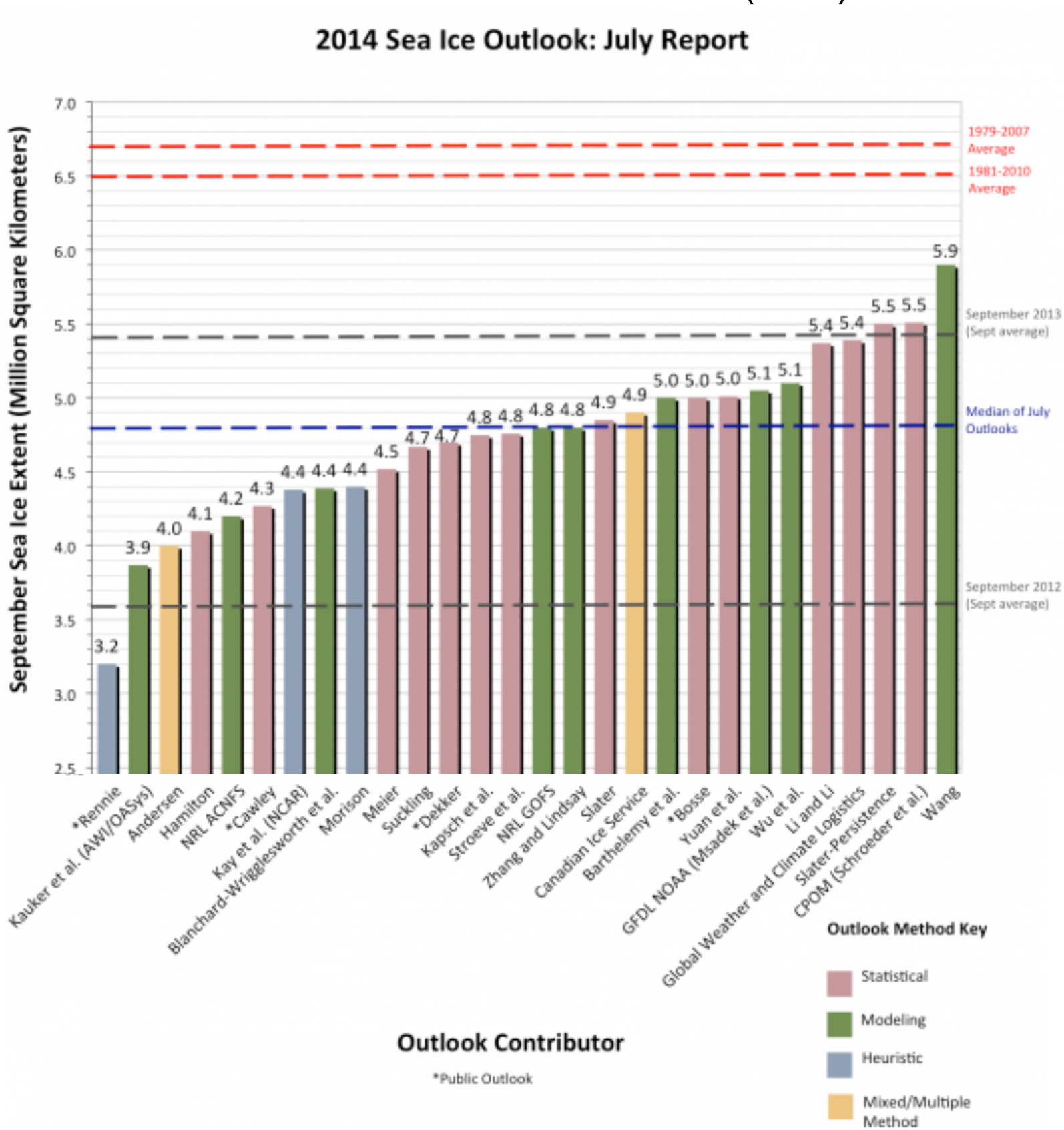
While sea ice extent is of very little practical use to stakeholders, it is generally a simpler problem than prediction of regional fields.

Lots of attention (200k unique views)

Average Monthly Arctic Sea Ice Extent
September 1979 - 2014

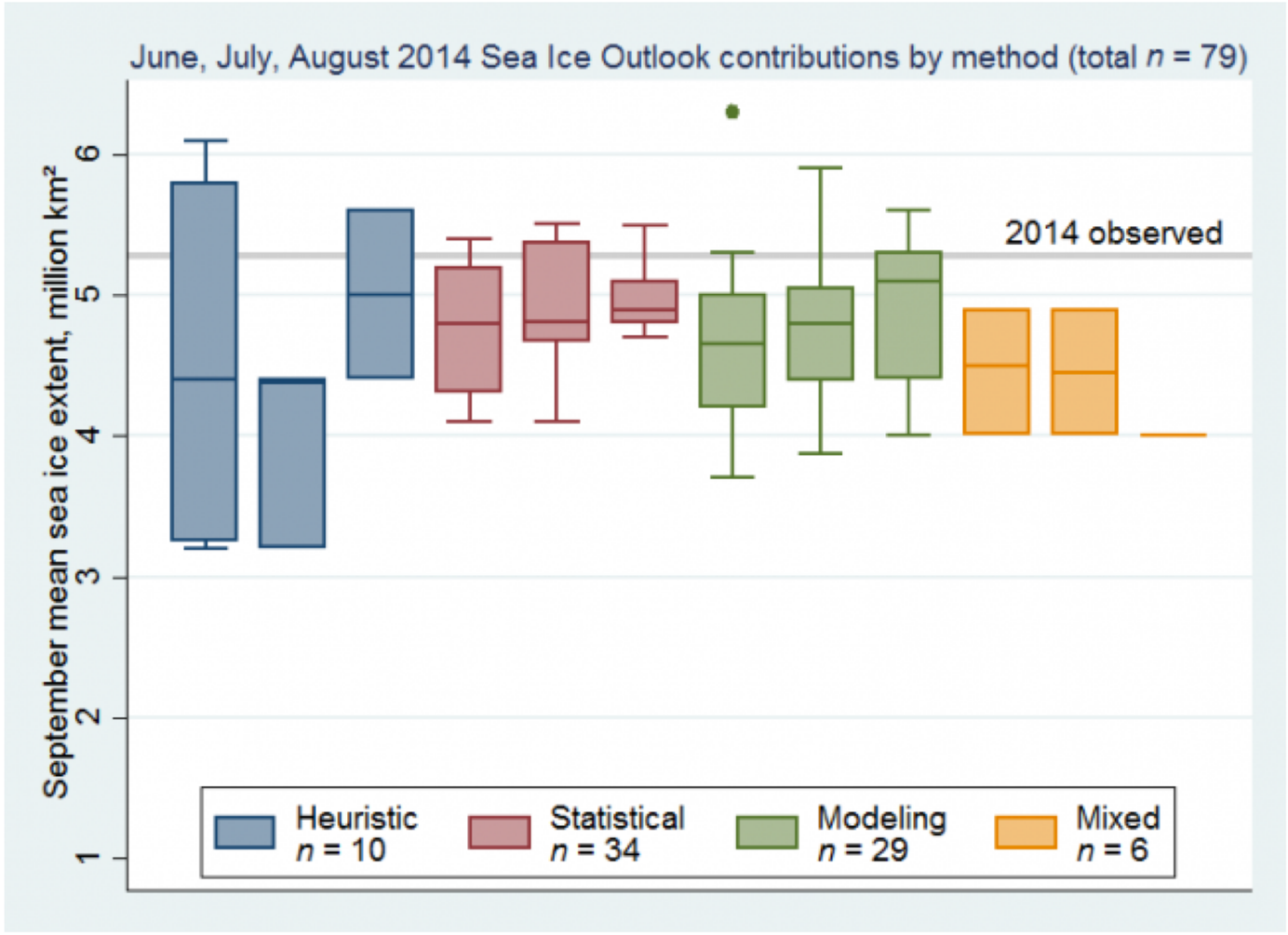


The Sea Ice Outlook (SIO)



(+/- sigma)

The Sea Ice Outlook (SIO)

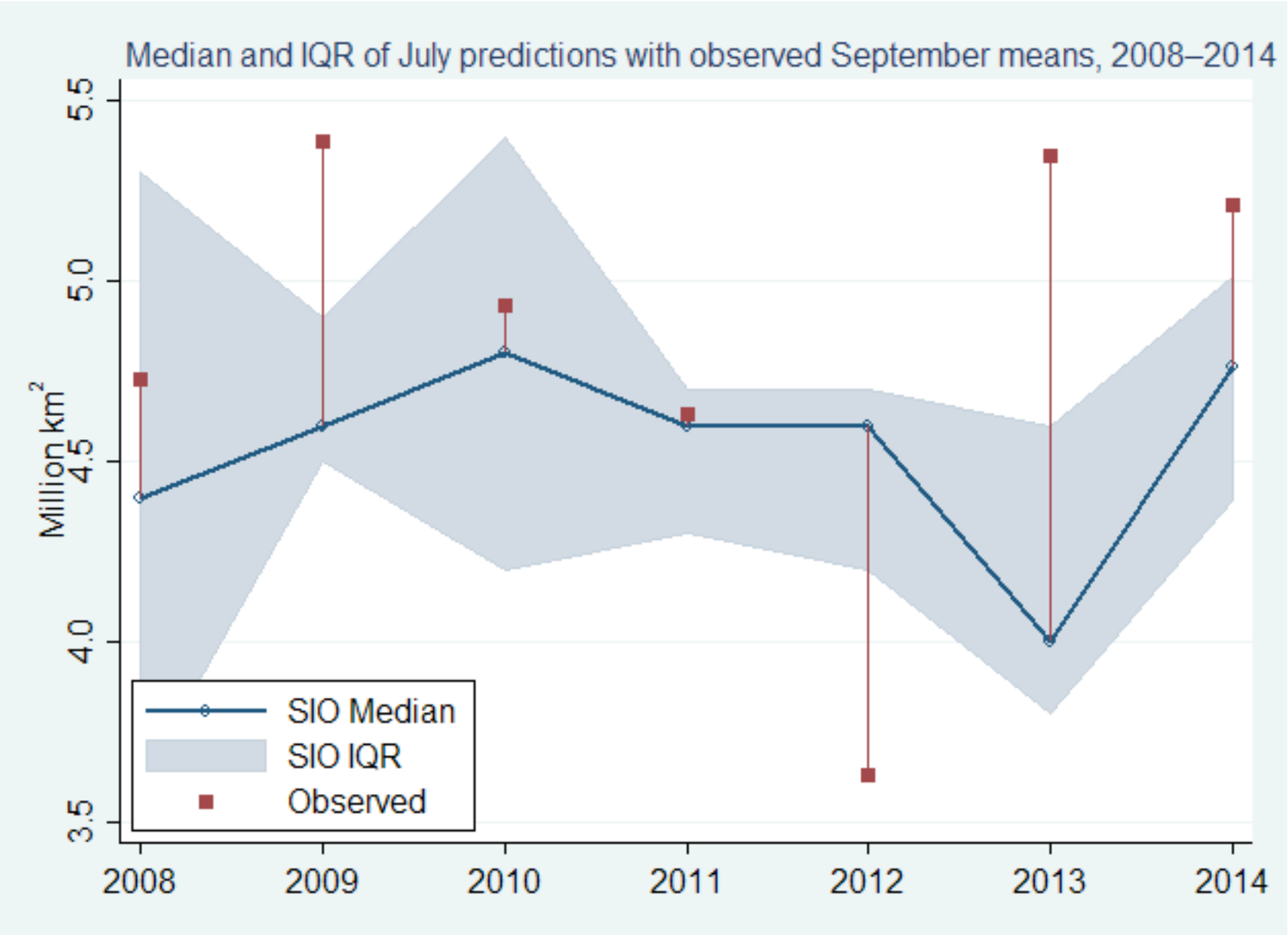


Statistical methods in 2014:
-Gompertz curve fit (similar to linear forecast) using previous Septembers (Hamilton)
-Persistence of past daily extent change rates (Meier)
-'Dynamic Climatology' = mean September 2007-2013 plus anomalies of all Septembers
-Regression of spring NH snow cover and June 'melt-ponds/polynya' (extent-area) (Dekker)
-Regression of spring atmospheric water vapor (Kapsch et al)
-Regression of ice age / survival (Stroeve et al)
-Spring Melt-pond area regression (Schroeder et al)

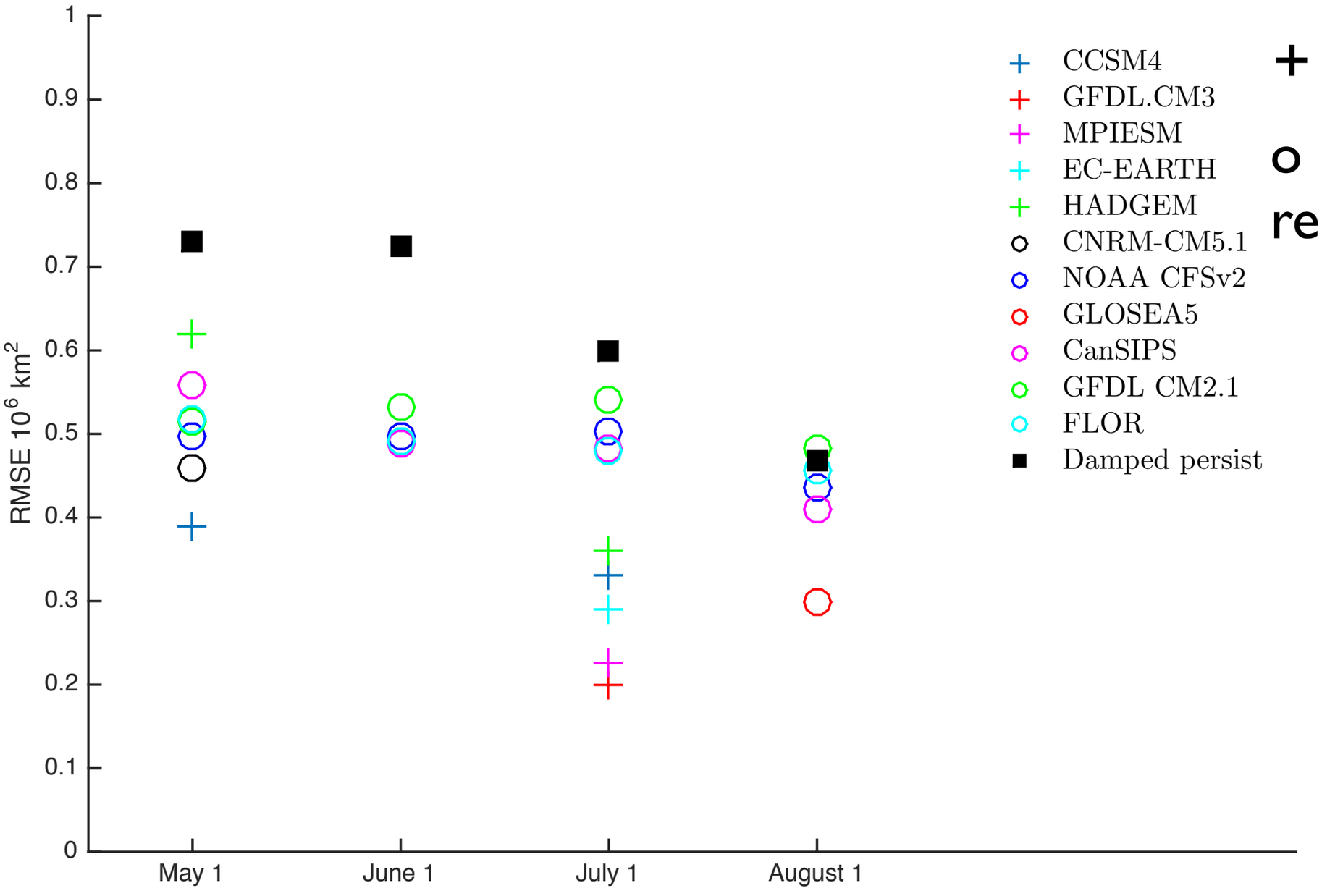
What is the Sea Ice Outlook (SIO)

2008 - 2014: 7 years, 21 submission calls, 300+ submissions. 112 from dynamical models.

Skill first analysed for 2008-2013 in Stroeve et al 2014



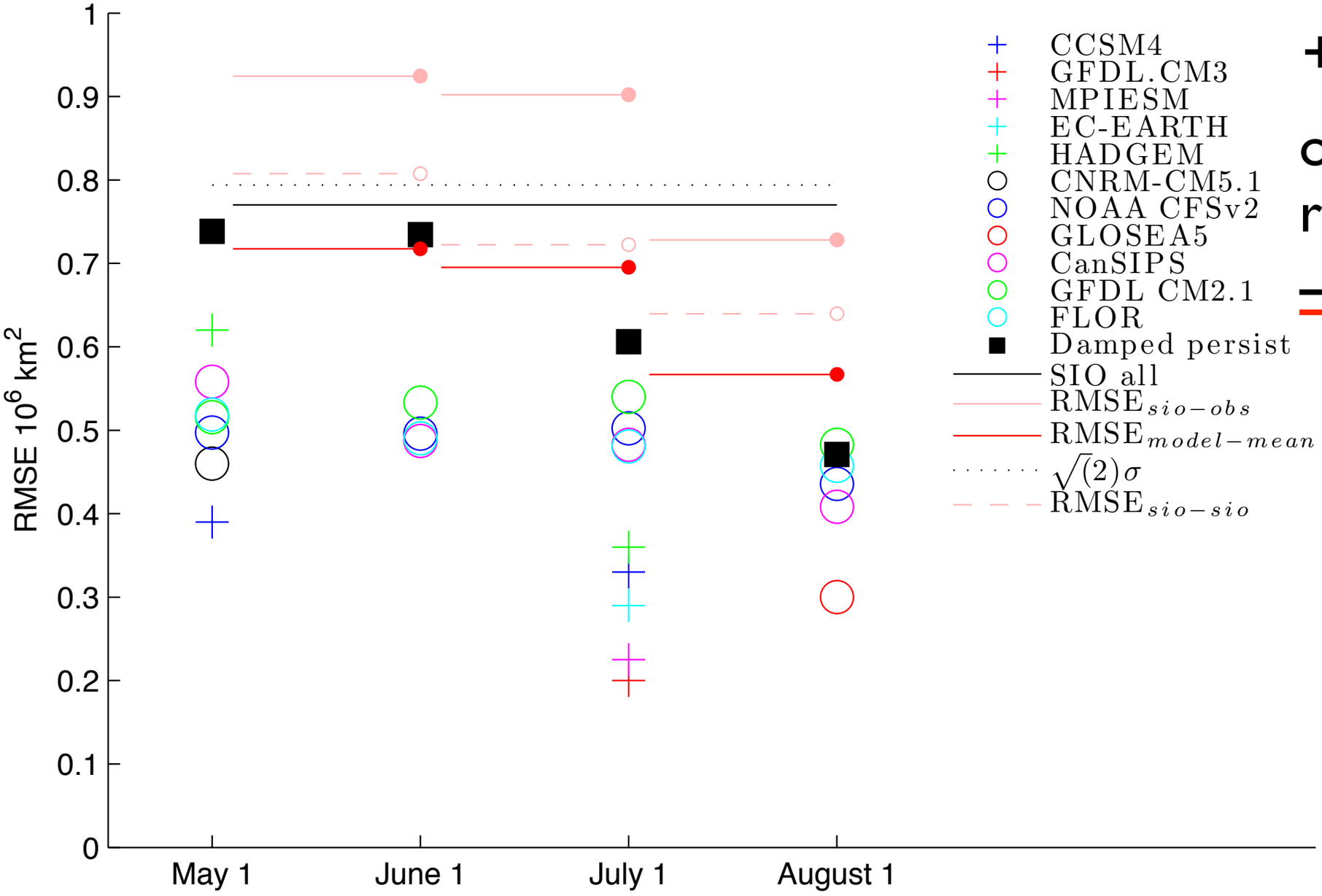
What is the skill in September sea ice forecasts?



+ Perfect-model

o Hindcasts Satellite record (1979 onward)

What is the skill in September sea ice forecasts?



+ Perfect-model

o Hindcasts Satellite record (1979 onward)

= SIO dynamical

What is the Sea Ice Outlook (SIO)

Strove et al (2014): Overall, little skill. Good when years are close to linear trend, poor when years depart from linear trend.

Statistical forecasts slightly better than dynamical models.

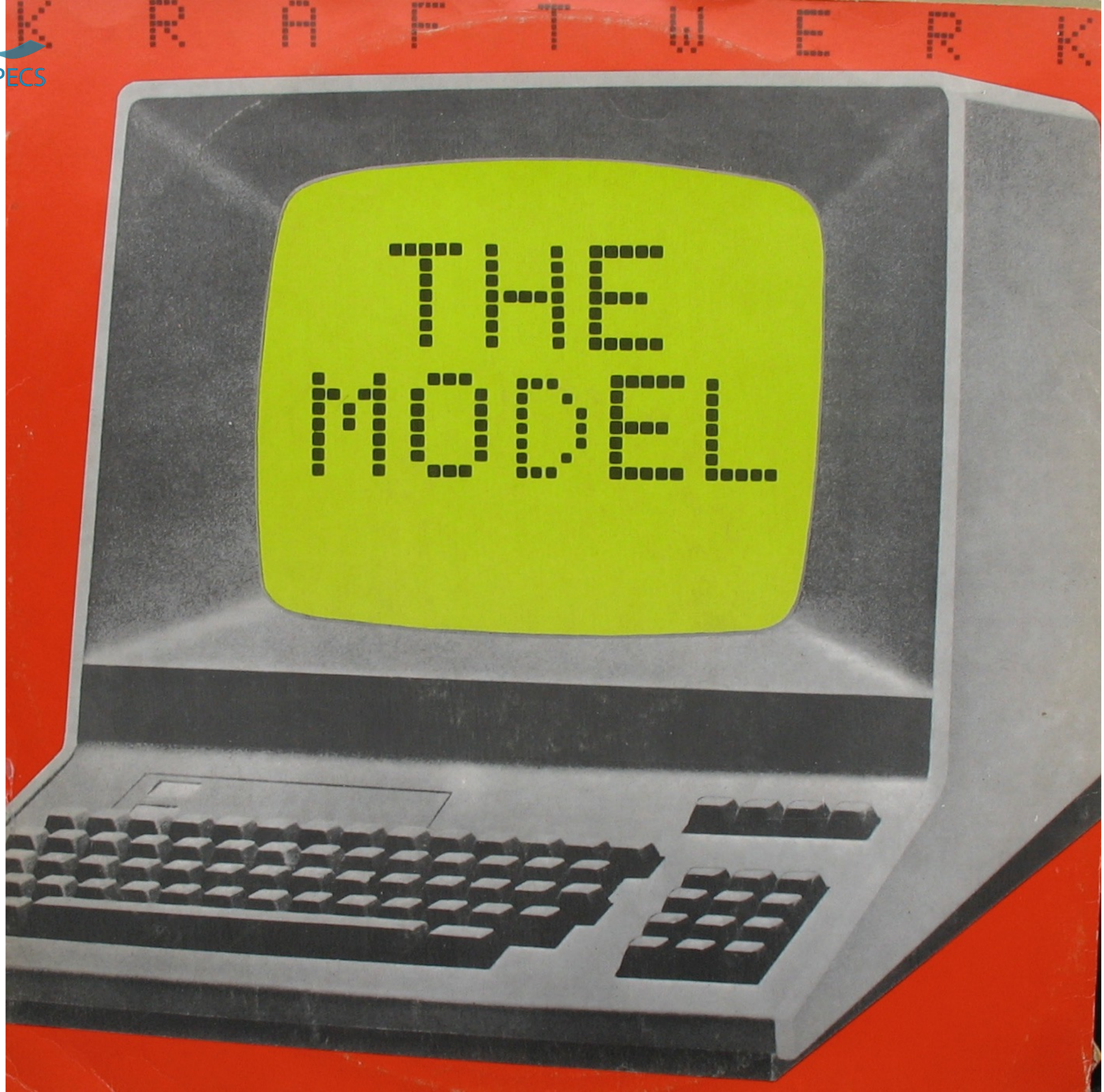
Not much improvement as season progresses (lead 4 month to lead 2 month forecasts)

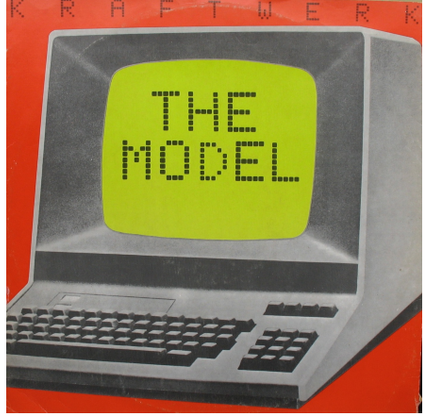
In this talk...

Develop a new* statistical model for the Arctic, compare skill with simple models.

*method used in Antarctic sea ice prediction (Chen & Yuan, 2004), ENSO prediction (Blumenthal 1991, Canizares et al, 2001) and East Asian monsoon forecast (Wu et al, 2013), and inspired by Yuan et al (in review… then rejected)

KRAFTWERK





We develop a multi-variate principal component analysis markov chain model

Let V be the (spatial dimension)*(sampling dimension - time) multivariate matrix of anomalies for month *i*, that we decompose into its eigenvectors and PCs:

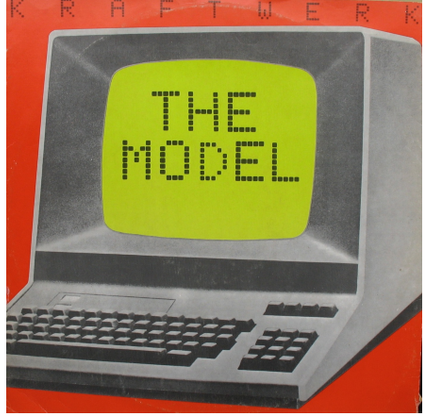
$$V_i=E_iP_i^T$$

And C the ‘transition’ matrix that satisfies:

$$P_{i+1}=CP_i + e_i$$

Multiply by P_i^T and average gives us:

$$\langle P_{i+1}P_i^T\rangle=C\langle P_iP_i^T\rangle+ \langle e_iP_i^T\rangle$$



Which since $\langle e_i P_i^T \rangle = 0$ gives us

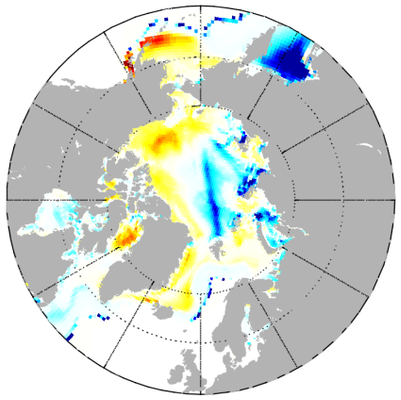
$$C = \langle P_{i+1} P_i^T \rangle / \langle P_i P_i^T \rangle$$

We calculate C during a training period of the model (e.g., first 100 years), for each month-to-month step.

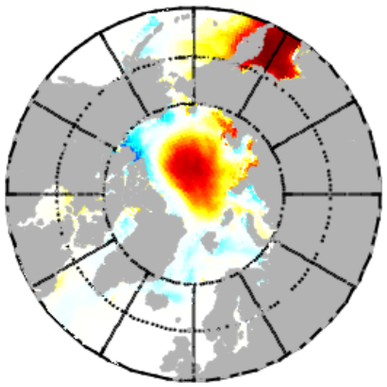
To make forecasts a time i to time T:

1) Project anomalies at time i onto Ei, to get the PCs
2) Use C to calculate future PCs
3) Future Ei * Future PCs = Future anomalies
4) Integrate future anomalies to get extent anomaly

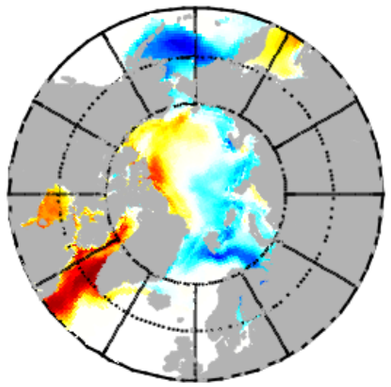
Observation at time *i*



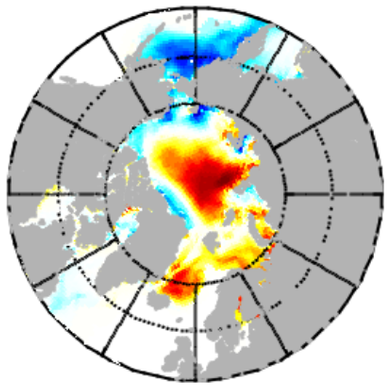
EOF1i



EOF2i



EOF3i



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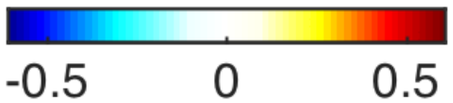


PC1i

xCit

PC1t

x

EOF1t

PC2i

PC2t

x

EOF2t

PC3i

PC3t

x

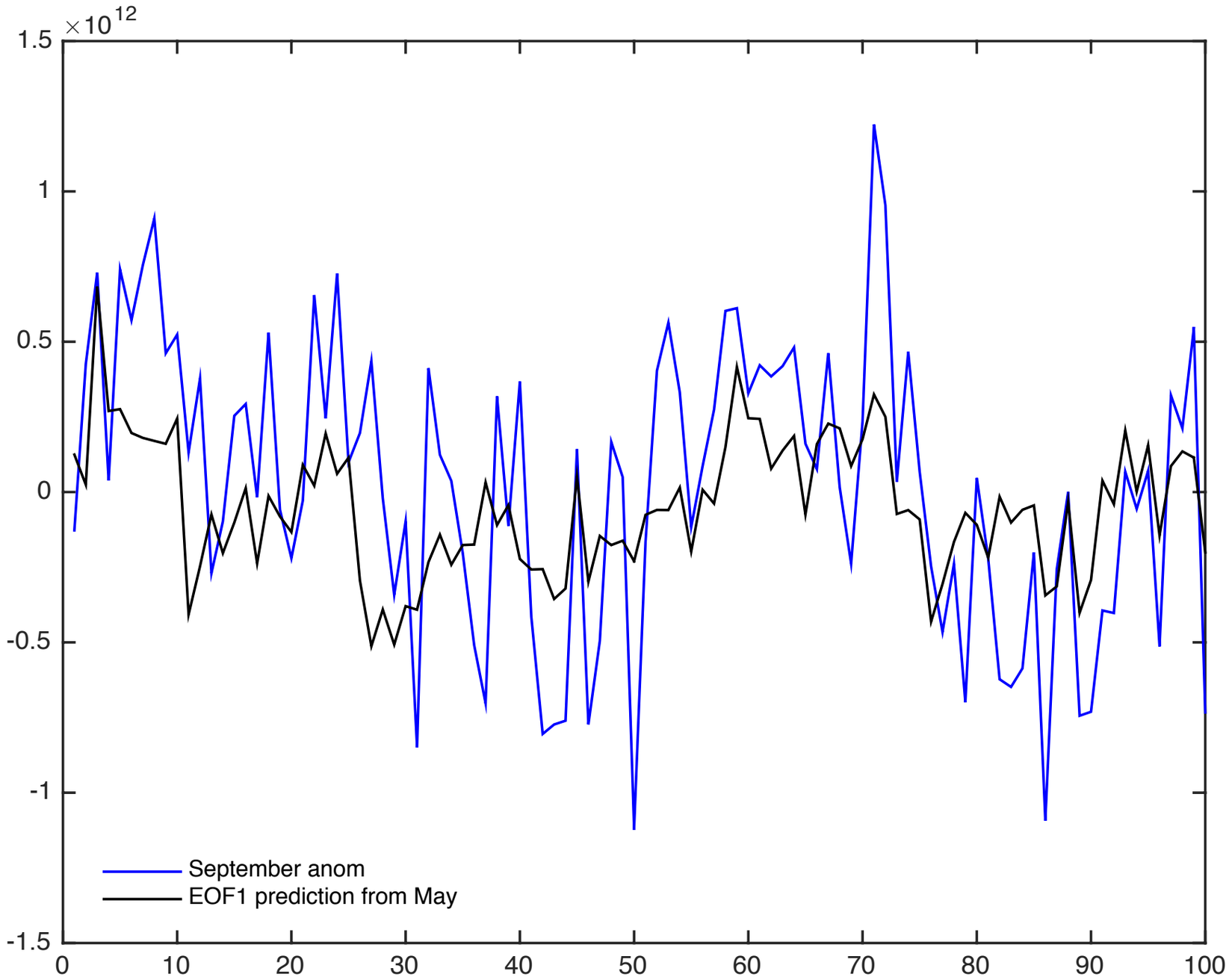
EOF3t

Forecast=sum(PCt*EOFt)

What can we tune in the model?

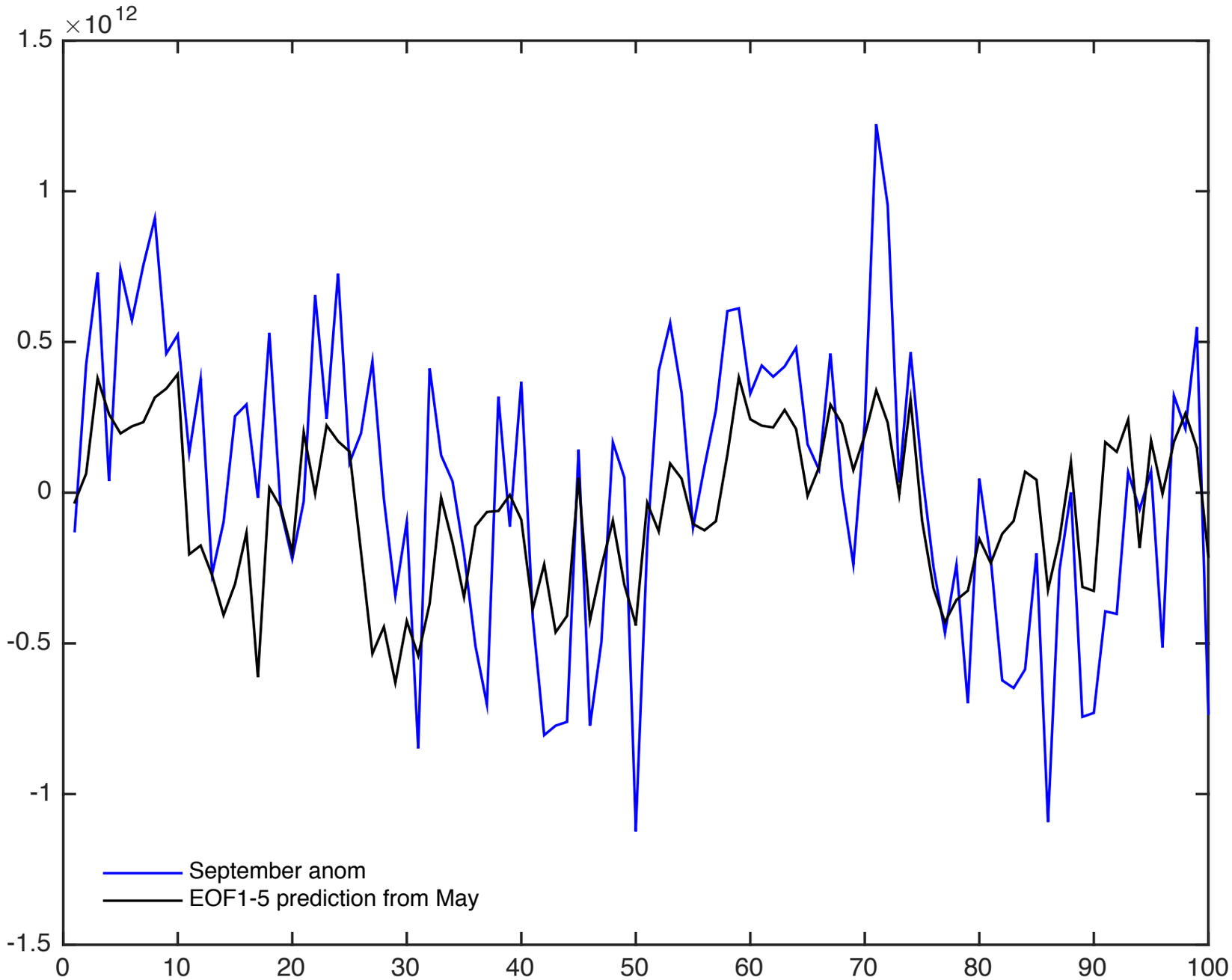
Which data to use - obs, GCMs?	ECEARTH, CESM cntl runs
Length of training years	50 & 100 years
Number of EOFs (&PCs) retained	1 -> 15
What variables go into model	SIC, SIC+SIT, SIC+SIT+SST

Does it ‘work’?



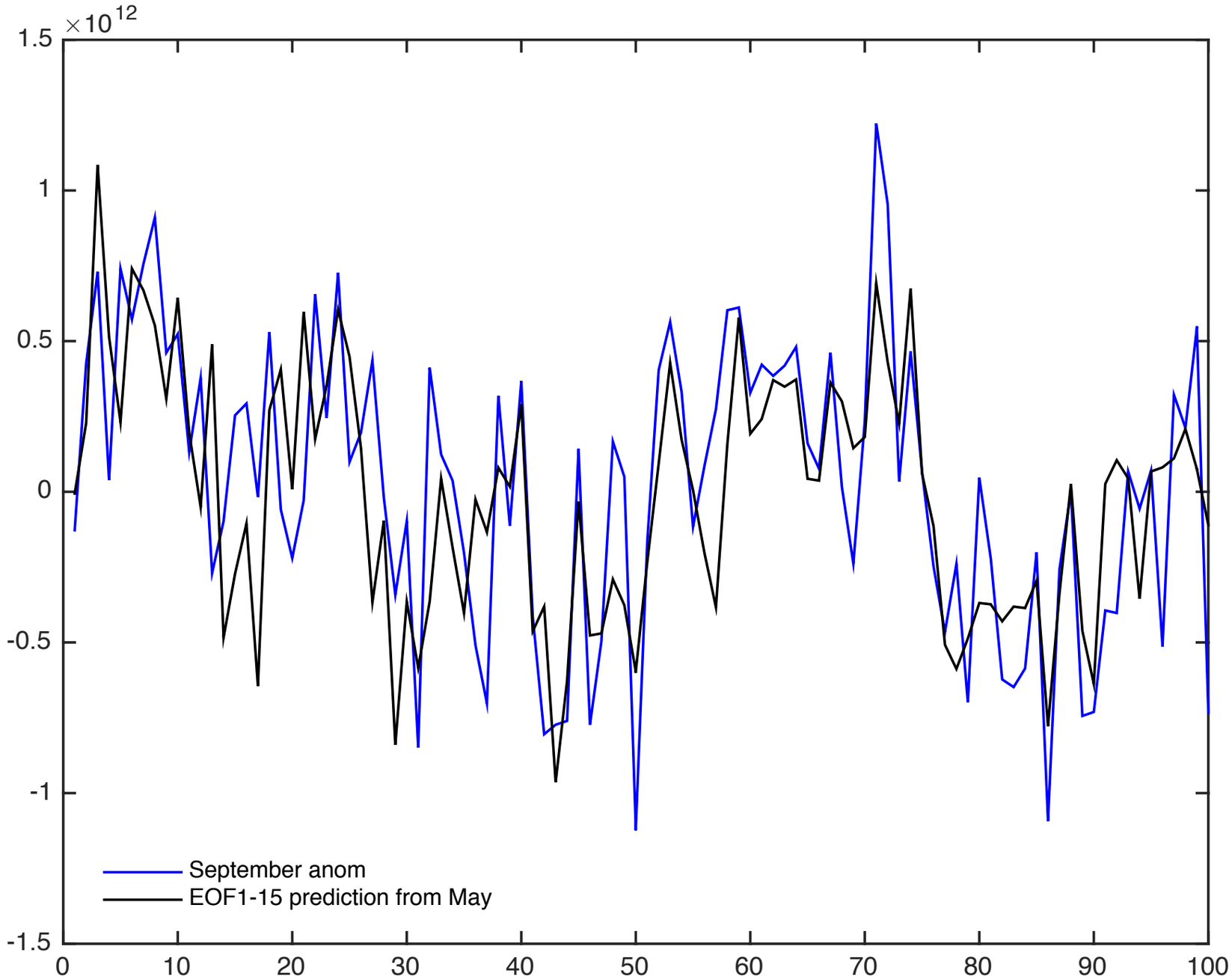
ECEARTH forecast

Does it ‘work’?



ECEARTH forecast

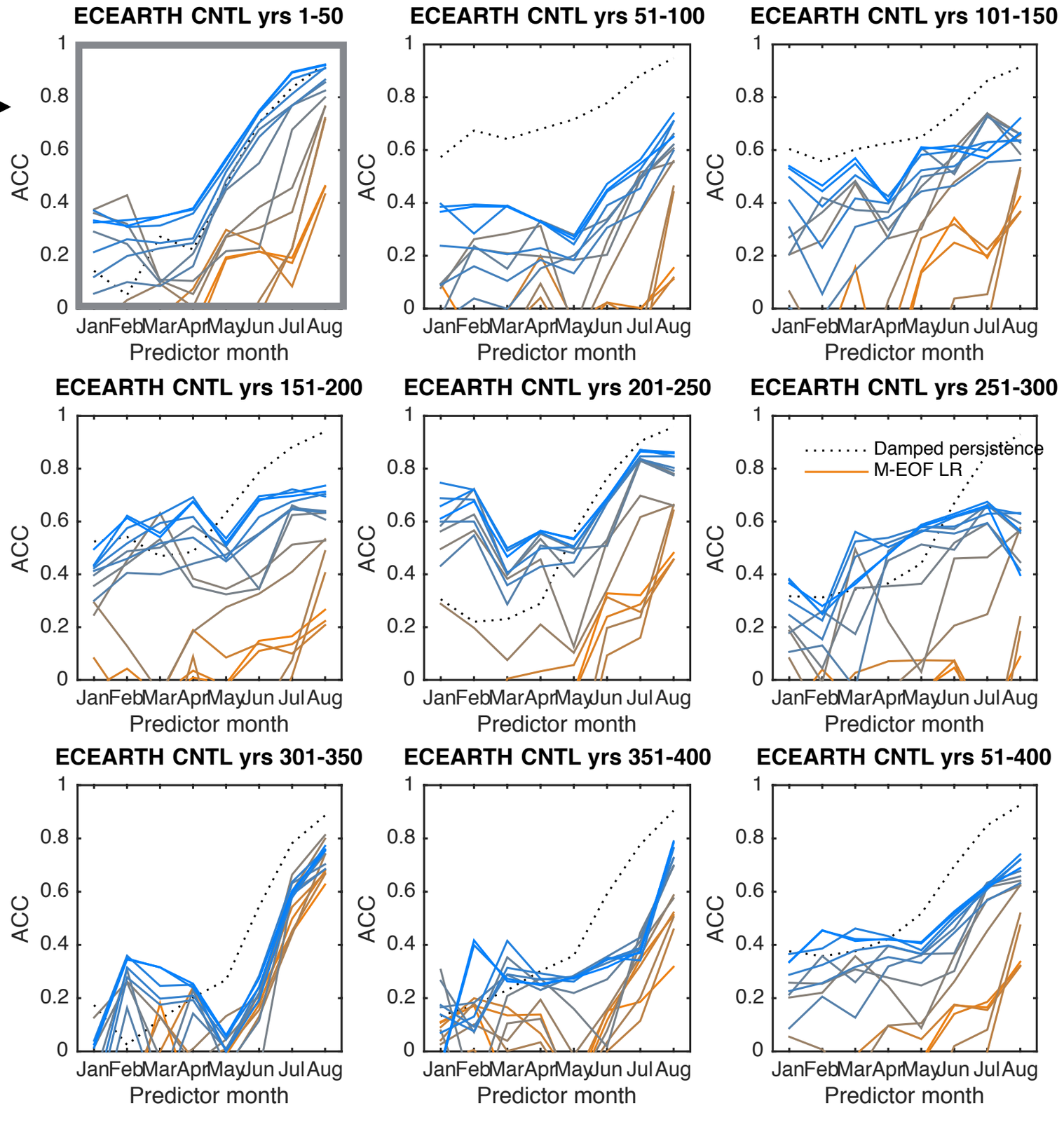
Does it ‘work’?



ECEARTH forecast

EC-EARTH, train years 1-50, sea ice concentration

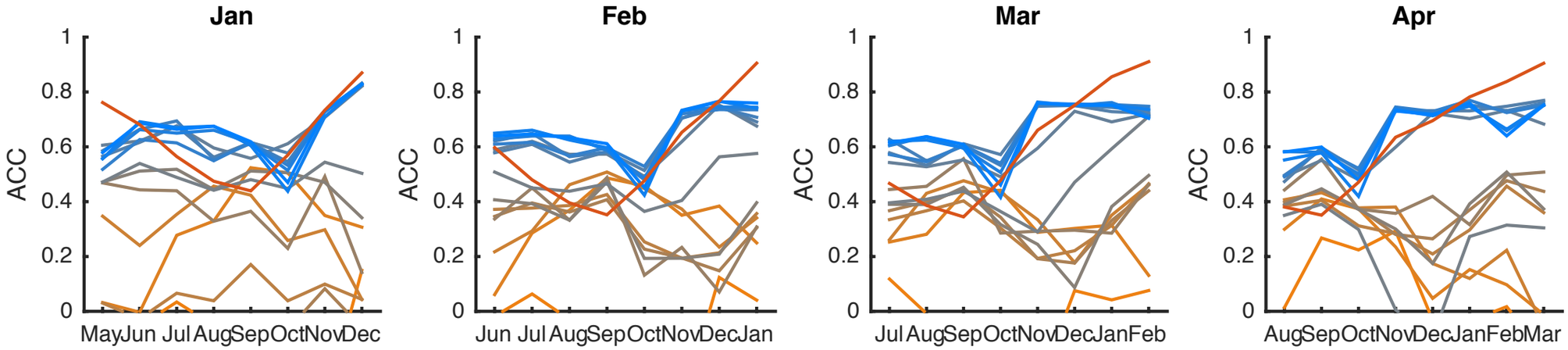
Not cross-validated!



EOF 1

EOF 1-15

EC-EARTH, train years 1-100, sea ice concentration



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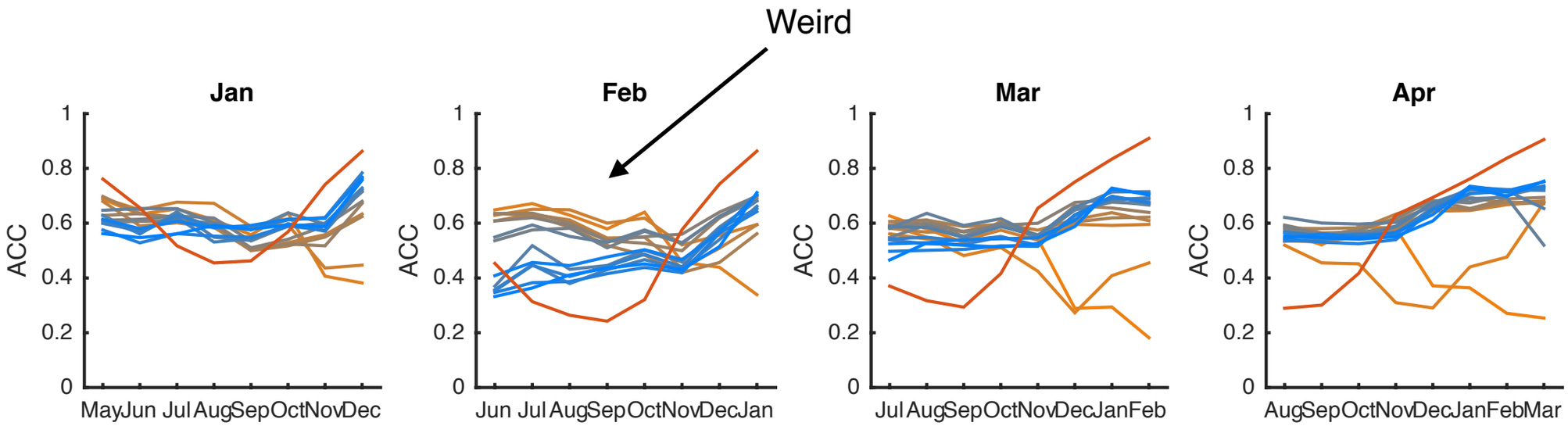
Univariate regression of total anomalies

EC-EARTH, train years 1-100, sea ice concentration+thickness



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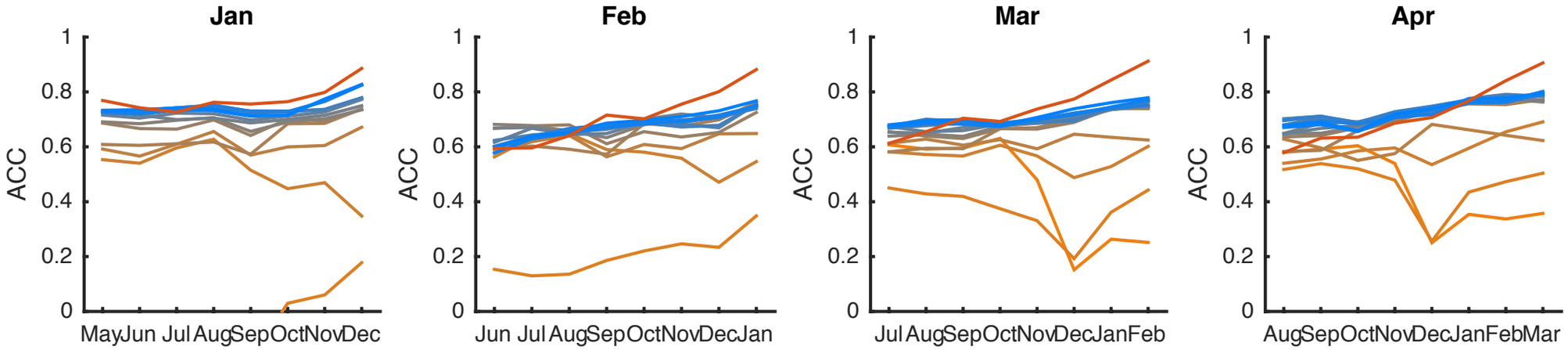
Multivariate regression of total anomalies

EC-EARTH, train years 1-100, SIC SIT & SST



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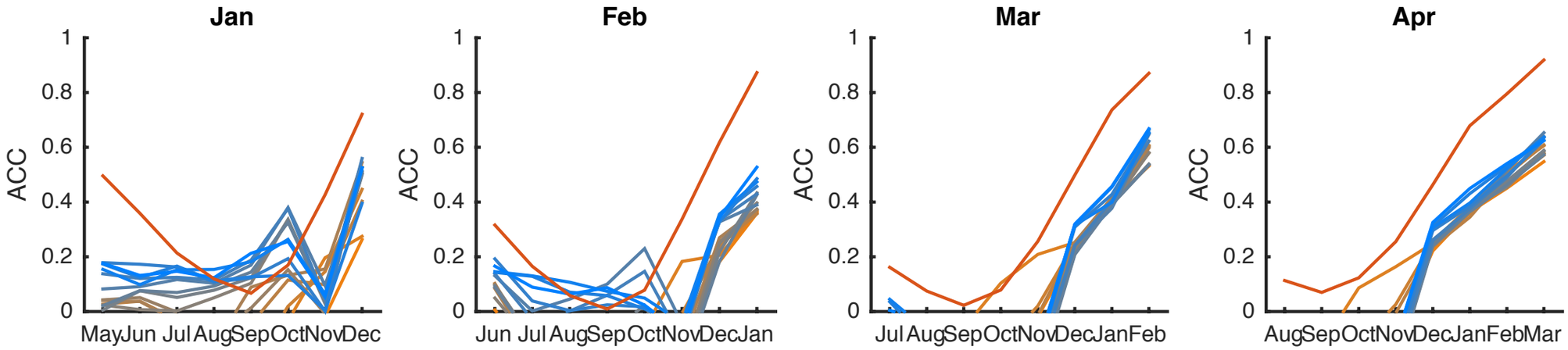
Multivariate regression of total anomalies

CESM1, train years 1-100, sea ice concentration



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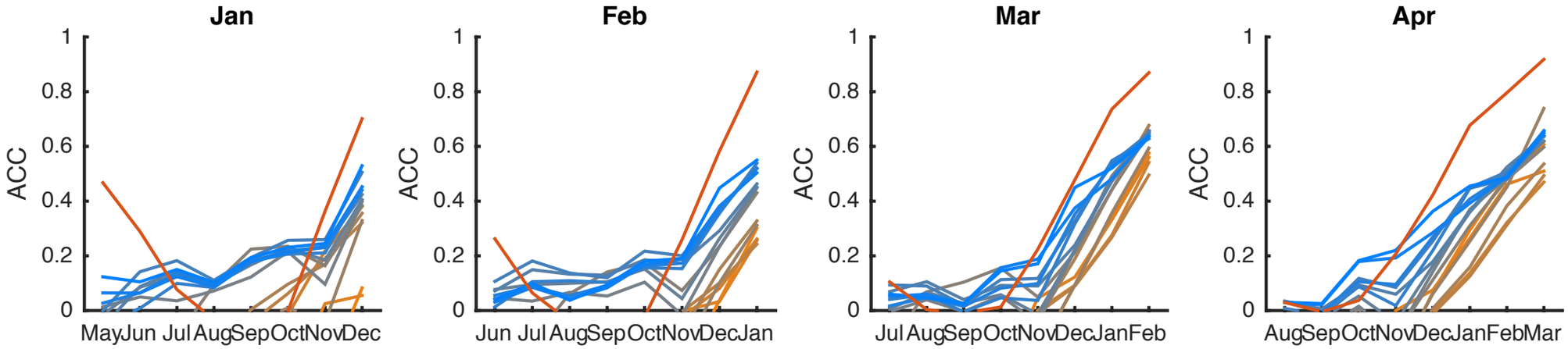
Univariate regression of total anomalies

CESM1, train years 1-100, sea ice concentration+thickness



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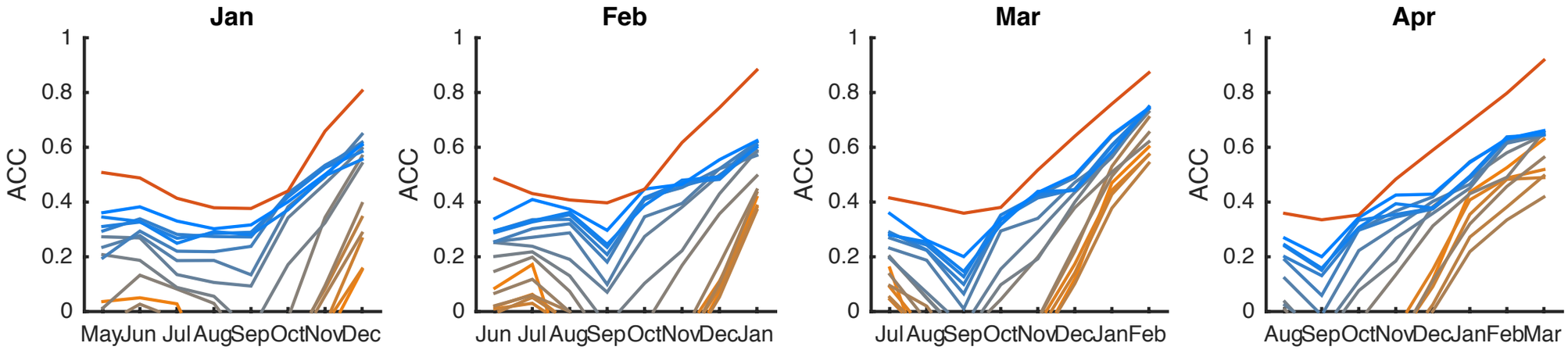
Multivariate regression of total anomalies

CESM1, train years 1-100, SIC SIT & SST

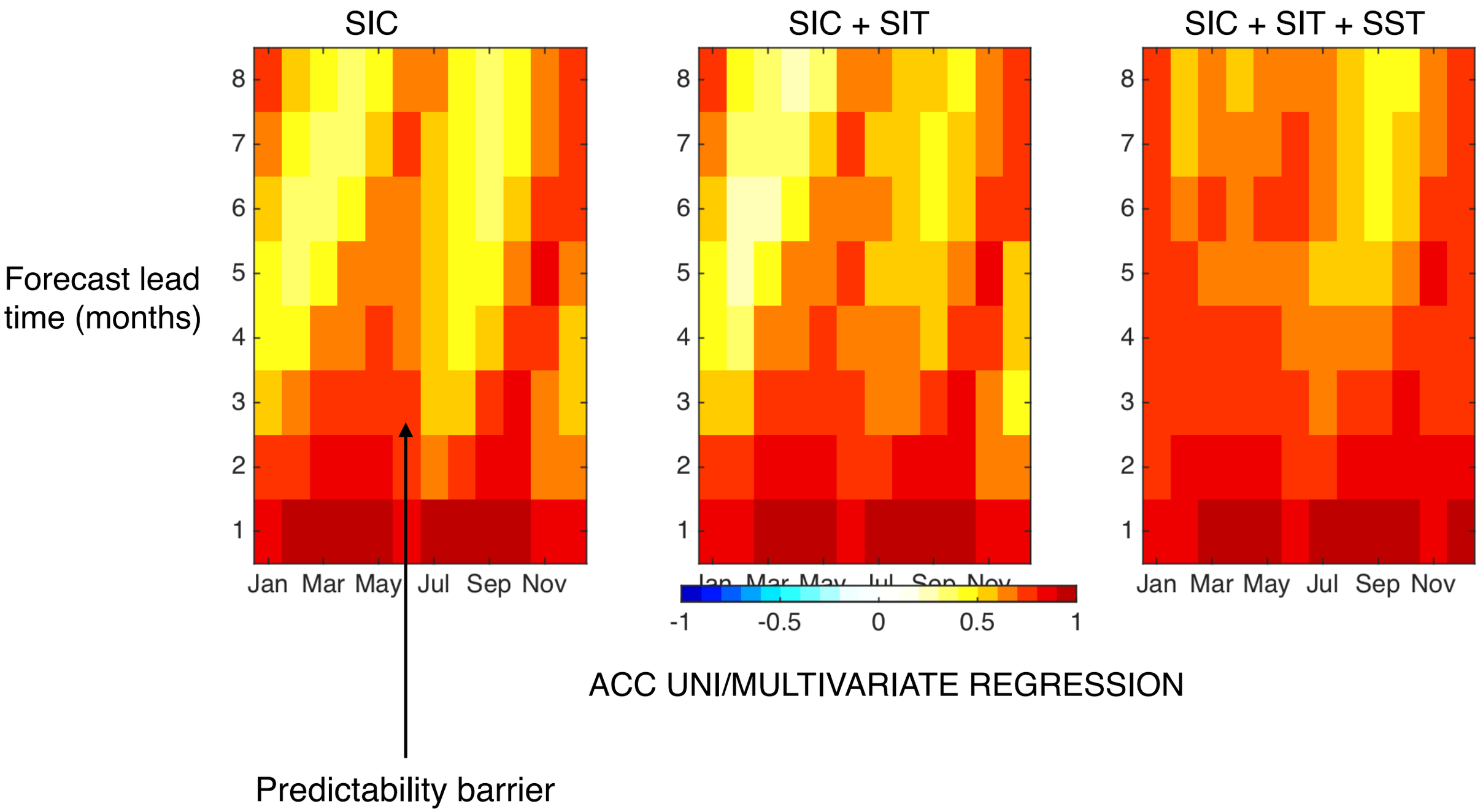


EOF 1

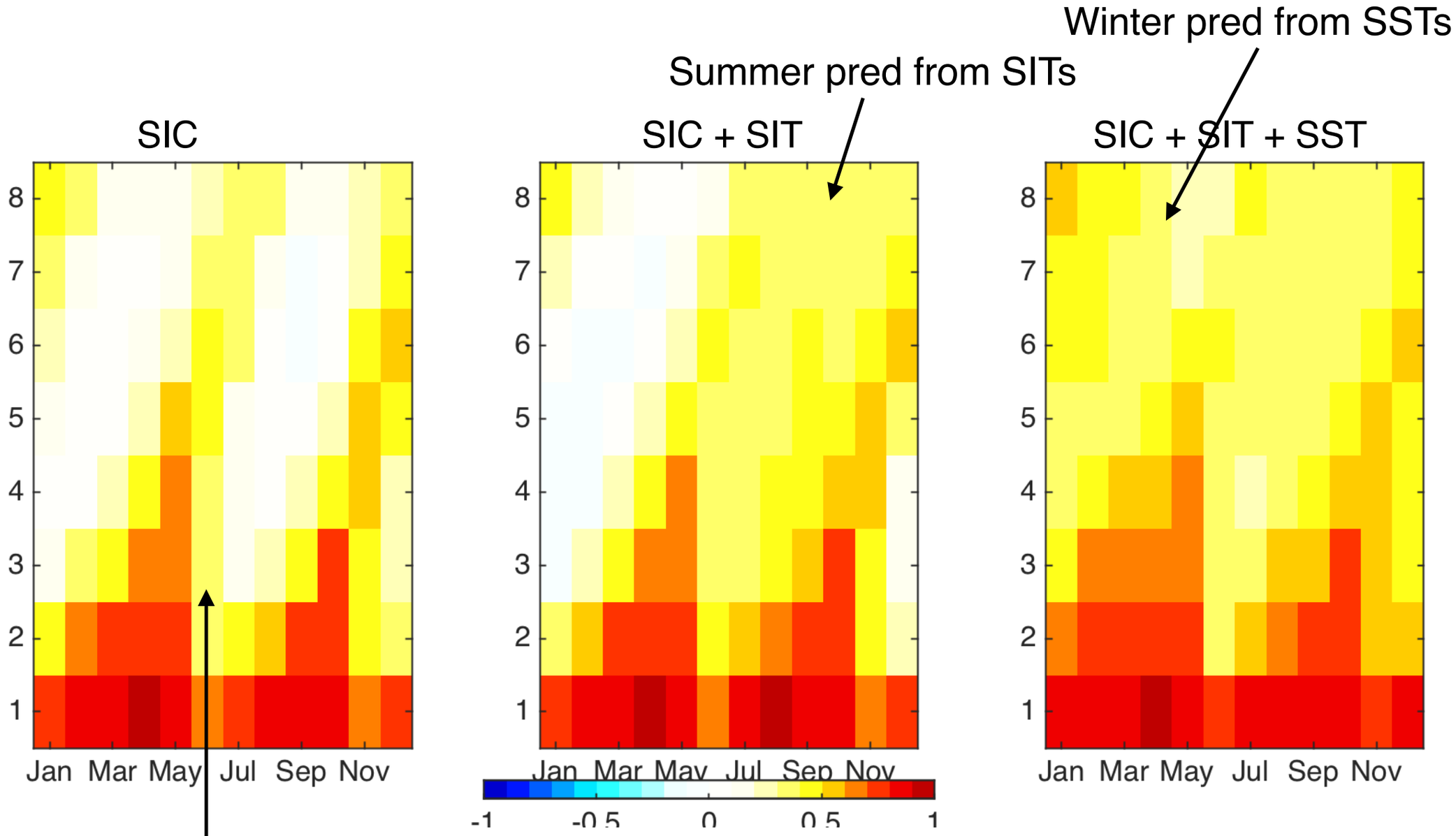
EOF 1-15

Multivariate regression of total anomalies

EC-EARTH


SIC
SIC + SIT
SIC + SIT + SST
Forecast lead time (months)
8
7
6
5
4
3
2
1
Jan Mar May Jul Sep Nov
-1 -0.5 0 0.5 1
ACC UNI/MULTIVARIATE REGRESSION
Predictability barrier

CESM1


Winter pred from SSTs
Summer pred from SITs
SIC
SIC + SIT
SIC + SIT + SST
Forecast lead time (months)
8
7
6
5
4
3
2
1
Jan Mar May Jul Sep Nov
-1
-0.5
0
0.5
1
ACC UNI/MULTIVARIATE REGRESSION
Predictability barrier

Multi-EOF Markov Chain - uni(multi)variate regression

SIC

SIC + SIT

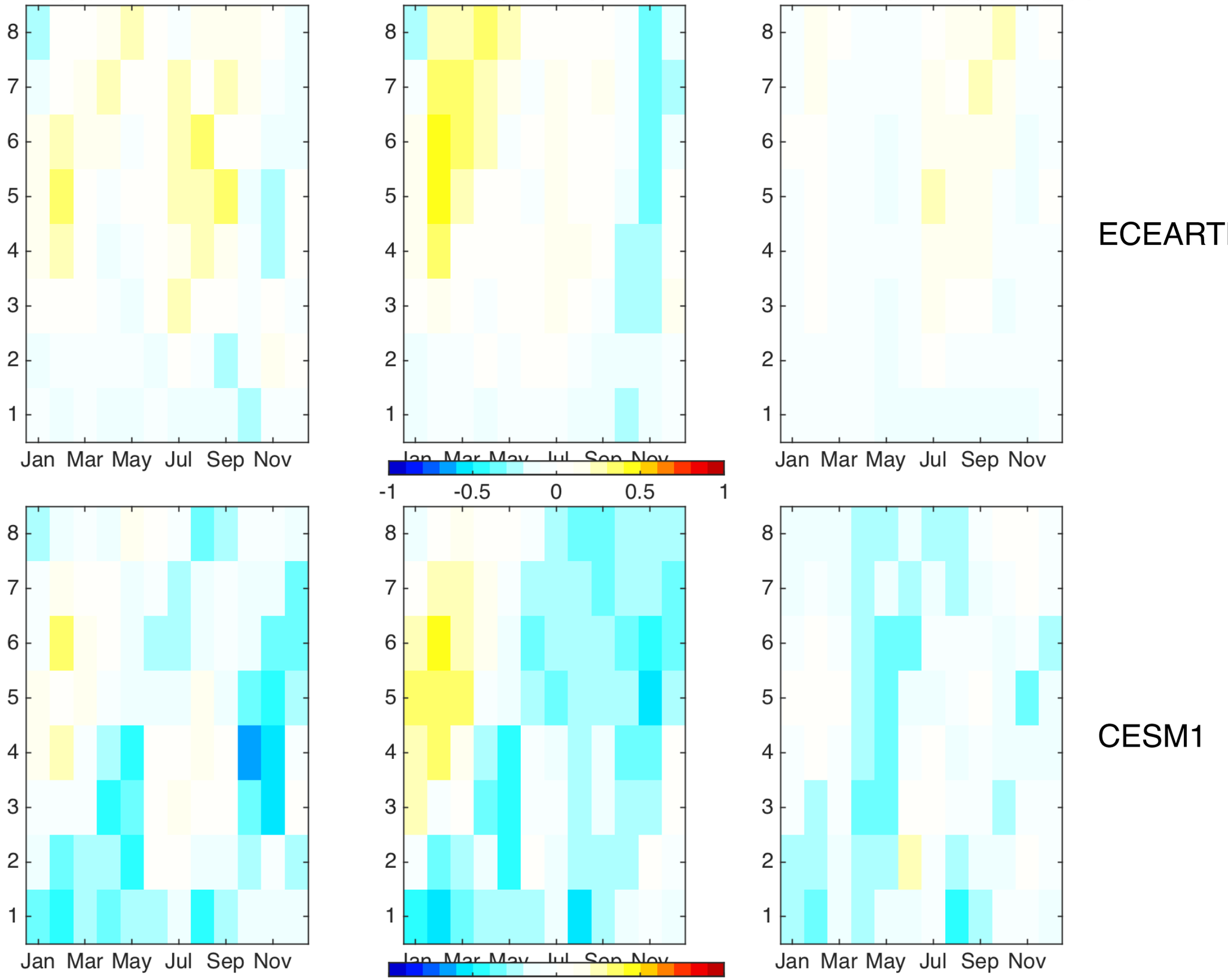
SIC + SIT + SST

Forecast lead time (months)

ECEARTH

Forecast lead time (months)

CESM1



How good is the model?

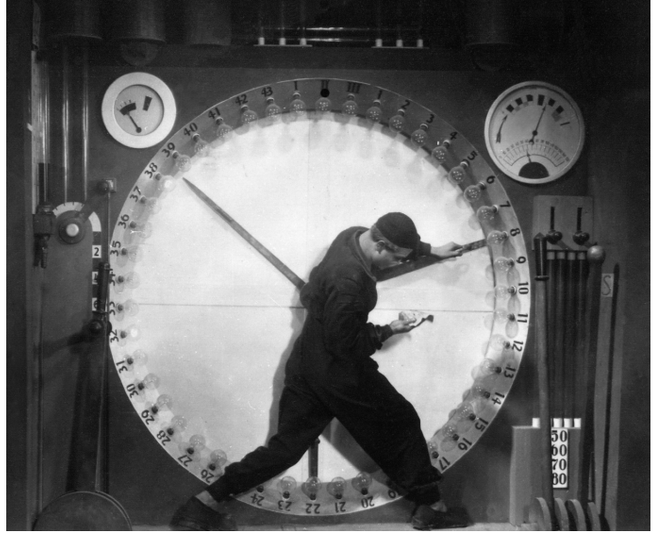
Not very good. At short lead times (1-2 months) it ‘never’ beats uni/multi regression.

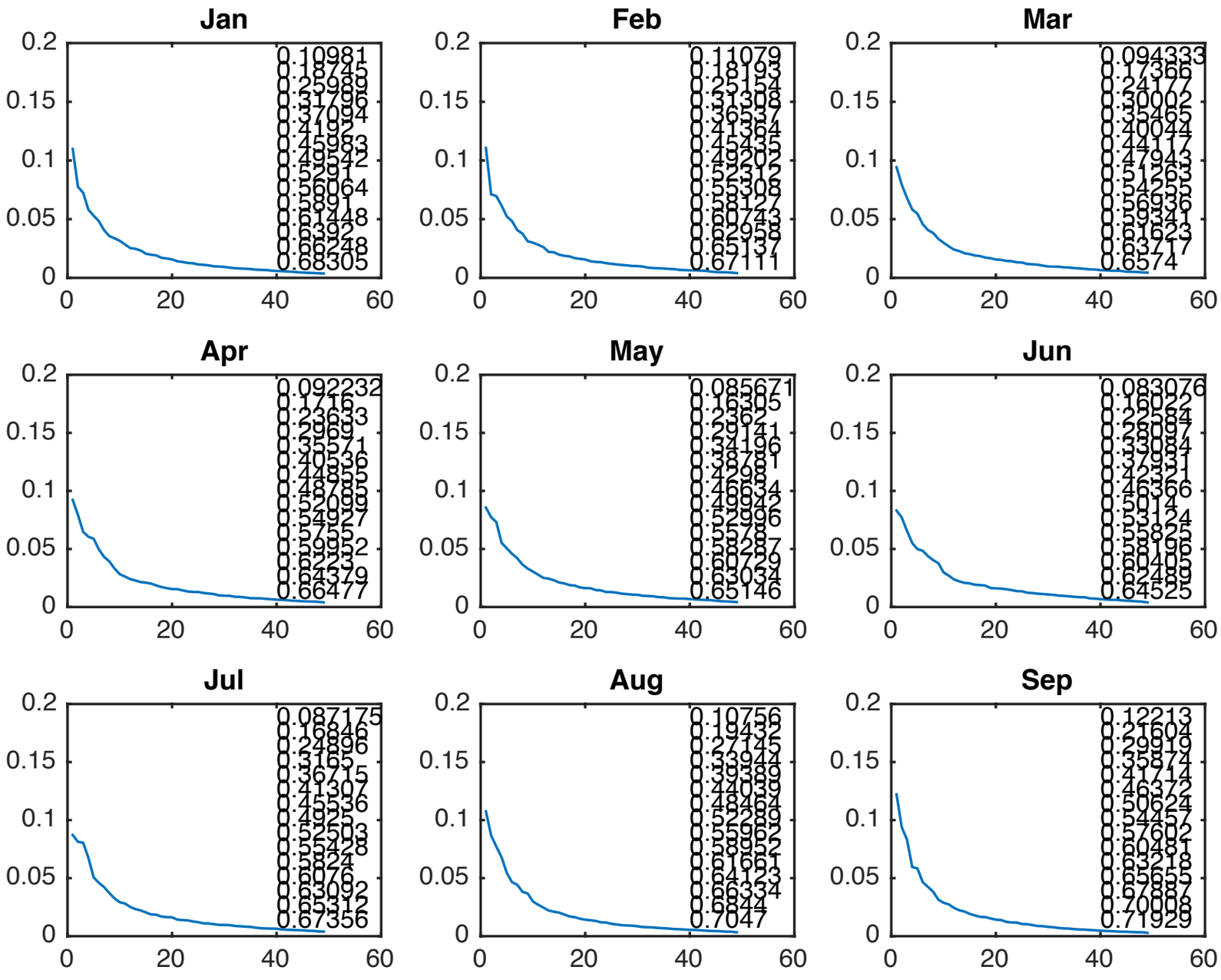
Some evidence that skill over regression is seasonally dependent. Winter forecasts at 5-8 month lead times using SIC or SIC & SIT hold promise

Also skill over regression model dependent. E.g., forecasts of September ice extent model beats regression in ECEARTH, not CESM1

Why is model not very good? Immediately lose information with initial EOF filtering. Arctic sea ice variability is not strongly dominated by first few EOFs? (in unforced run). Propagate errors in Markov chain.

…However!! Skill is likely to be region-dependent. Possible that in some is useful





Eigenvalue spectrum of SIC

EC-EARTH, train years 1-100, SIC + SIT